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Development of a method and decision support system for distributing orders of a machine-building enterprise

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Abstract. The efficiency of the machine-building enterprise depends on the efficiency of management decisions at all levels, which affect the implementation of production orders, rational use of production resources. The use of modern information technologies which are based on mathematical methods allows you to make the right management decisions in a timely manner to improve the efficiency of the enterprise.

1. Introduction

The use of modern technologies in the machine-building enterprise is a driver of increasing the productivity of personnel, which directly affects the financial and economic condition of the enterprise. The use of modern technologies, such as decision support information systems, helps the decision-maker to select the necessary recommendations based on data obtained from information systems [1-3] (MES-systems) installed in the structural divisions of the enterprise. The system in question has several systems, namely, a simulation system, a dynamic situation modeling system, each of which is responsible for its own analysis function. Loading data into the simulation model allows you to get the results that are closest to reality, which are then compared with the existing optimal result, which is made in the system for modeling dynamic situations. The transmitted data for decision-making can be, for example, the current capacity utilization of a structural division, the availability of necessary personnel, and the level of manufacturing defects for inventory items. The effectiveness of timely decisions is reflected in the performance of structural divisions, their ability to complete tasks within the specified time frame. If an enterprise has duplicate divisions that can produce the same product range, there will be a need to distribute production orders between them in different proportions. To determine the effective distribution of orders between duplicate divisions, the decision support system must have a mechanism (for example, a mathematical method) that takes into account this specific feature. Use in the model simulation [4-6], namely, models based on multi-agent approach [7-8], a mathematical method of allocation of orders will provide the necessary result which will be compared against the optimal solution that will allow you to see how the process will work when you implement it, without spending a lot of time and resources.

2. Formulation of the problem

A machine-building enterprise that includes metallurgical and Assembly production is considered. Metallurgical production involves four workshops that form a single technological chain for manufacturing and transporting it to the Assembly plant. The manufacturing process begins with metal



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smelting, then two production lines, with different production capacities, produce the billet and ends with the Assembly of the finished product. The distribution of an order list between two production lines is not an easy task, which must take into account both the production time and the profit that is generated in the shop based on the incurred costs. One of the solutions to the problem can be the use of a simulation system with the developed model and the method of "re-ordering" orders embedded in it, taking into account the specific feature of the enterprise.

3. Theory

The method of "re-engineering" of production orders has been developed for efficient loading of the same type of structural divisions at a machine-building enterprise. The General task of manufacturing products at a large machine-building enterprise is considered, which has the following form:

$$S_i = \langle \text{Shop}_j(P_k), Z_t^i, T_{i0}, T_{ie} \rangle$$

Shop_j – production shop;

P_k – estimated production capacity of the shop;

Z_t^i – production order;

T_{i0} – the start time of the order;

T_{ie} – the time when the order should be completed.

The criterion for the effectiveness of the distribution is the maximum allowable capacity utilization to fulfill orders on time with minimal costs for their implementation, where c_i – the cost of materials and labor, depreciation of equipment in the shop when performing the i -th order, c_v – the cost of reducing production volumes.

Due to the fact that the process of manufacturing products at the enterprise is associated with the availability (limitation) of the necessary resources, the problem statement is presented as a linear programming issue. The target function of the order distribution task has the following form:

$$\sum_{i=1}^m (c_i) + c_v \rightarrow \min$$

The organization of the process of distribution of production orders between the same type of structural divisions is actually reduced to operational management of existing production capacities and solving the problem of dispatching.

The simulation model has been extended by an intelligent agent that analyzes the current situation based on collected data from other agents, and makes a decision on the real location of production orders between structural divisions. The structure of the stages of solving the problem when building an enterprise order distribution system looks like this:

- Determining the initial conditions for the task of re-ordering orders;
- Generating orders based on information about the current available capacity in structural divisions;
- Building a system of linear equations based on the initial data, solving the problem by simplex method (Figure 1) for distributing orders on each route, obtaining the optimal solution;
- Verification of the obtained results taking into account restrictions that are not taken into account when constructing a system of linear equations in a model implemented in a simulation environment.
- Getting a plan for distributing orders along existing technological routes.

To solve this problem and obtain an optimal plan for distributing orders between departments, the BpSim.DSS dynamic situation modeling system was used. In this system, a model was created with a sequence of actions to be taken when searching for a solution, which includes the labor intensity of production based on the technological processes of manufacturing parts in each structural division, the allowable number of products rejected by the Central quality Department, the availability of personnel, and the maximum allowable load of departments. The solution of a system of linear equations in the process of finding solutions to the problem is distributing orders along production routes.

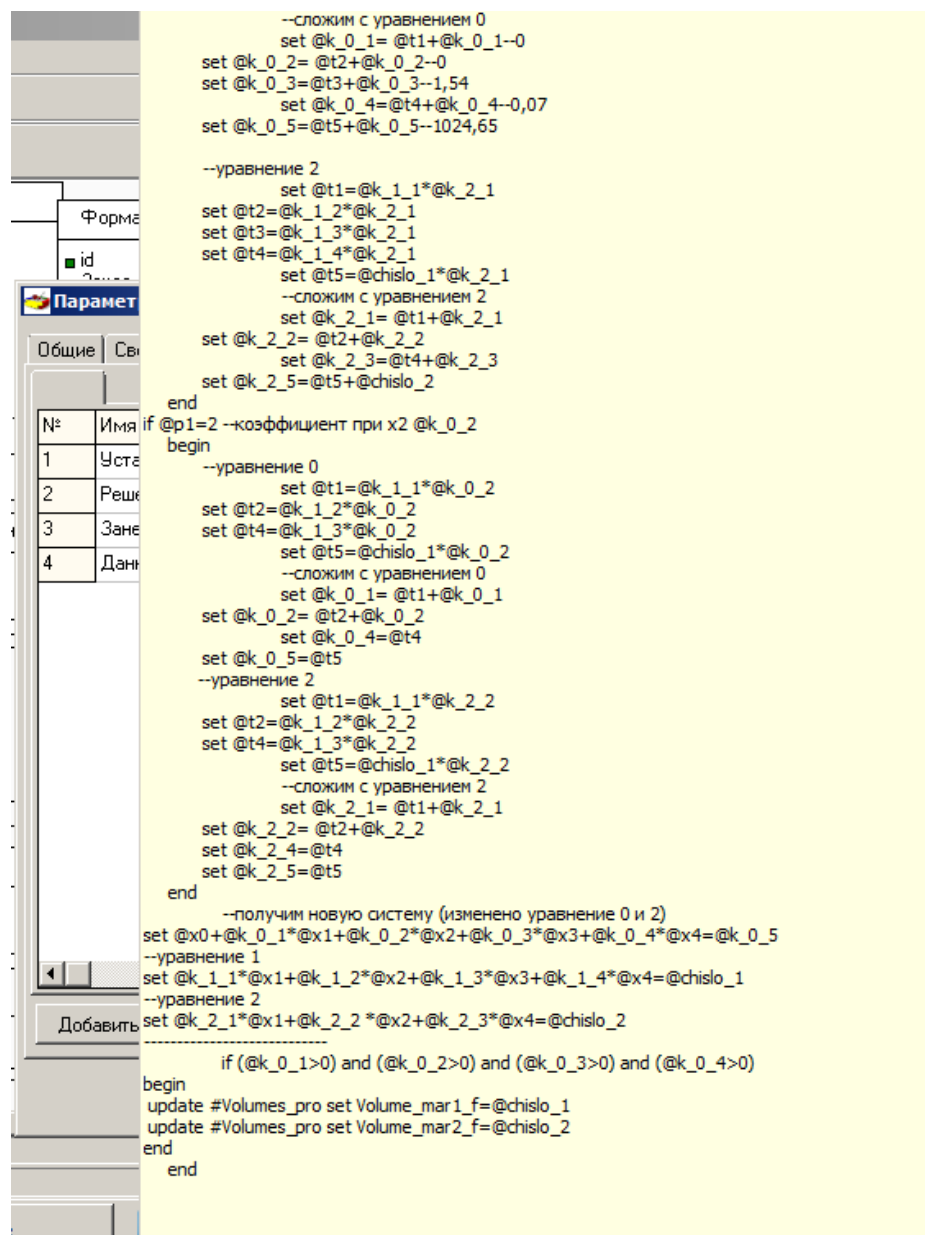


Figure 1. Fragment of a programmed simplex method in the Transact SQL language

The resulting solution is optimal and serves as a reference point for comparative calculations. To get a plan for the distribution of orders between divisions, a model was built using the Kanban approach and the method of "retargeting" (distribution) of orders in the BpSim.MAS simulation system, where the technology was developed for each of the routes, taking into account the used equipment, the level of defective products, and the maximum allowable load of divisions. Software agents (Figure 2) are used in structural divisions, since the items of the nomenclature have different production routes within the shop.

MPPR/Kanban

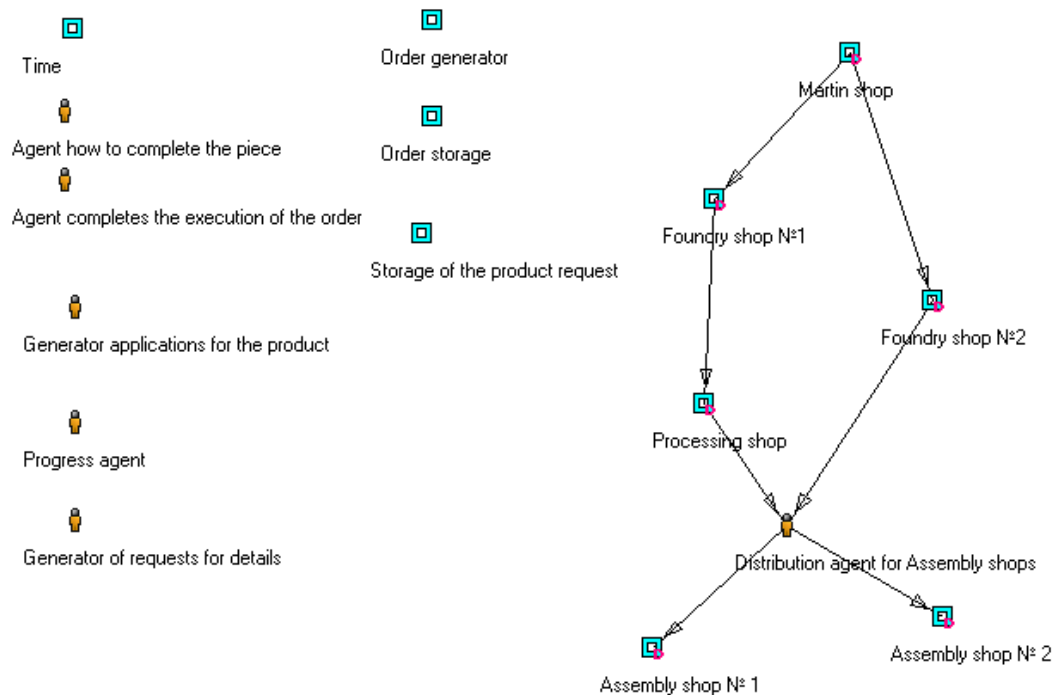


Figure2. Upper level of the model MPPR/Kanban

Software agents are based on rules that determine how the agent works in various situations.

4. Experimental results

The comparison was carried out of the following models: MPPR/Kanban, PV Network and Kanban. The results of experiments on efficient distribution of production orders are shown below (Table 1).

Table 1. Comparison of models

Parameters/Route (Model)	1/2 Kanban	1/2 PV-Network	1/2 MPPR/Kanban
Simulation time, days	30/30	30/30	30/30
The total number of nodes collected	70/86	80/73	104/88
The total number of completed orders	7/35	8/38	12/29
Total profit received by the enterprise	690/850	790/715	1175/868
Average load on routes	35%/38%	41%/38.5	45%/41%
Number of Order Distribution Agent Rules	7/7	15/15	10/10

5. Conclusion

The results obtained in the course of experiments demonstrate the advantages of using a model with the "re-engineering" method in comparison with others. The number of manufactured parts and Assembly units for large orders is higher by 33% (Kanban) and 23% (PV-Network), and for small batches - 2% (Kanban) and 17% (PV-Network). The BpSim dynamic situation modeling system.DSS, together with the simulation system BpSim.MAS, forms a decision support system for obtaining the effective result in machine-building enterprises.

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